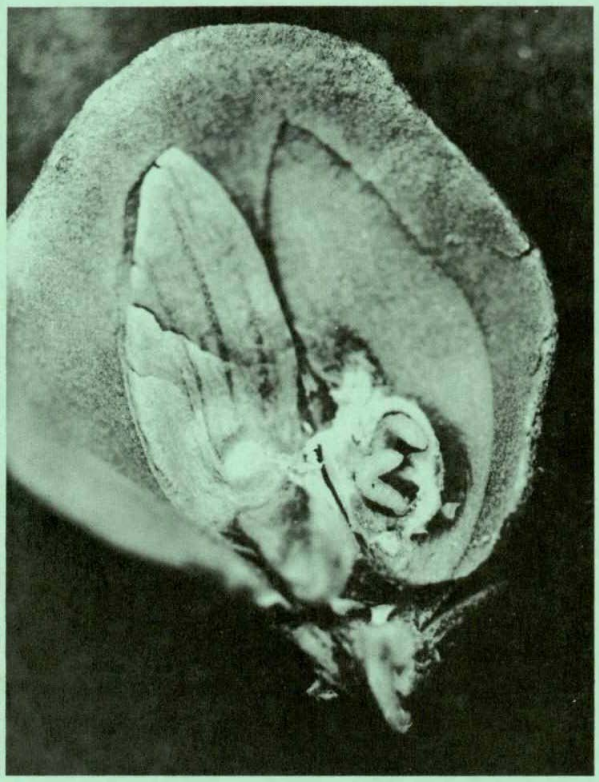
REPORT NO. 72-1

FEB 1972

A Three Year Evaluation of DOUGLAS-FIR CONE AND SEED INSECTS in Montana and Yellowstone National Park



U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
DIVISION OF STATE AND PRIVATE FORESTRY
NORTHERN REGION MISSOULA, MONTANA

5230

A THREE-YEAR EVALUATION OF DOUGLAS-FIR CONE AND SEED INSECTS IN MONTANA AND YELLOWSTONE NATIONAL PARK

by

Jerald E. Dewey, Entomologist
Forest Insect and Disease Branch

ABSTRACT

A 3-year evaluation of Douglas-fir cones in Montana and Yellowstone National Park, Wyoming, showed the western spruce budworm, Choristoneura occidentalis Freeman, and midges were the most common and injurious insects found each year. Injury was so severe at some plots that no sound seeds could be found.

INTRODUCTION

Douglas-fir is one of the nation's most important timber species. It is the principal cover type on over one-fourth (4,555,000 acres) of the commercial forest land in Montana (Wilson, A. K., and J. S. Spencer 1967). In 1970, approximately 450 million board feet of Douglas-fir were harvested in the State. Douglas-fir timber production will undoubtedly continue to play an important part in satisfying the need for increased wood products. Lower value stands will become increasingly important as demands intensify.

Since 1956, Douglas-fir has ranked number one in volume cut in Montana. Much of this cutover land, as well as burned over forest lands, has failed to naturally regenerate successfully. The unsatisfactory regeneration, especially in some areas east of the Continental Divide, has caused concern on the part of land managers and led to this evaluation.

Insects are known to feed heavily on Douglas-fir cones and seeds in many locales. Hedlin (1960) indicates that in some years the Douglas-fir cone moth, Barbara colfaxiana (Kearfott) destroys up to 100 percent of the Douglas-fir seed in some areas. The Douglas-fir cone midge, Contarinia oregonensis Foote, was considered responsible for destroying nearly 50 percent of the 1957 Douglas-fir seed crop in certain areas of the Pacific Northwest (Johnson and Heikkenen 1958).

In 1967, a study was initiated in Montana east of the Continental Divide and Yellowstone National Park to inventory the insects injurious to Douglas-fir cones and seeds (Dewey and Honing 1968). This study was expanded to four additional areas west of the Divide in 1968 (Dewey 1969). Cones were not collected in 1969 because of a near cone crop failure and other work priorities, but were sampled again in 1970. The overall objective of this study was to evaluate the effect cone and seed feeding insects have on Douglas-fir regeneration in the study area.

METHODS AND PROCEDURES

Nine plots were located at widely scattered locations in Montana and Yellowstone National Park in 1967 and increased to 13 in 1968. These plots represented a wide array of physical differences such as elevation, exposure, grade, stand density, stand age, and annual precipitation.

Cones were collected in equal numbers from three crown levels (upper third, middle third, lower third) in 1967. No effort was made to do this in 1968 or 1970 because of the lack of significant variation in insect counts by crown level in 1967.

Cones were collected in 1970 at monthly intervals beginning June 29 and continuing through September 25. Collections were made at the same location as in 1968 (Fig. 1). Three hundred cones were collected at each plot at each collection. Cones were laboratory analyzed by the method used in 1968 (225 dissected, 75 placed in rearing containers) (Fig. 2). Both cardboard ice cream cartons and screen-top, 2-quart jars were used as rearing cages. In the 3 years of the study 56,400 Douglas-fir cones were collected; 34,800 were dissected, the remainder placed in rearing containers.

After the cones had been in the rearing containers for several months they were refrigerated for about 6 weeks and replaced in rearing containers to obtain insects requiring cold treatment.

Insects recovered from the laboratory rearing were send to the U.S. National Museum for identification.

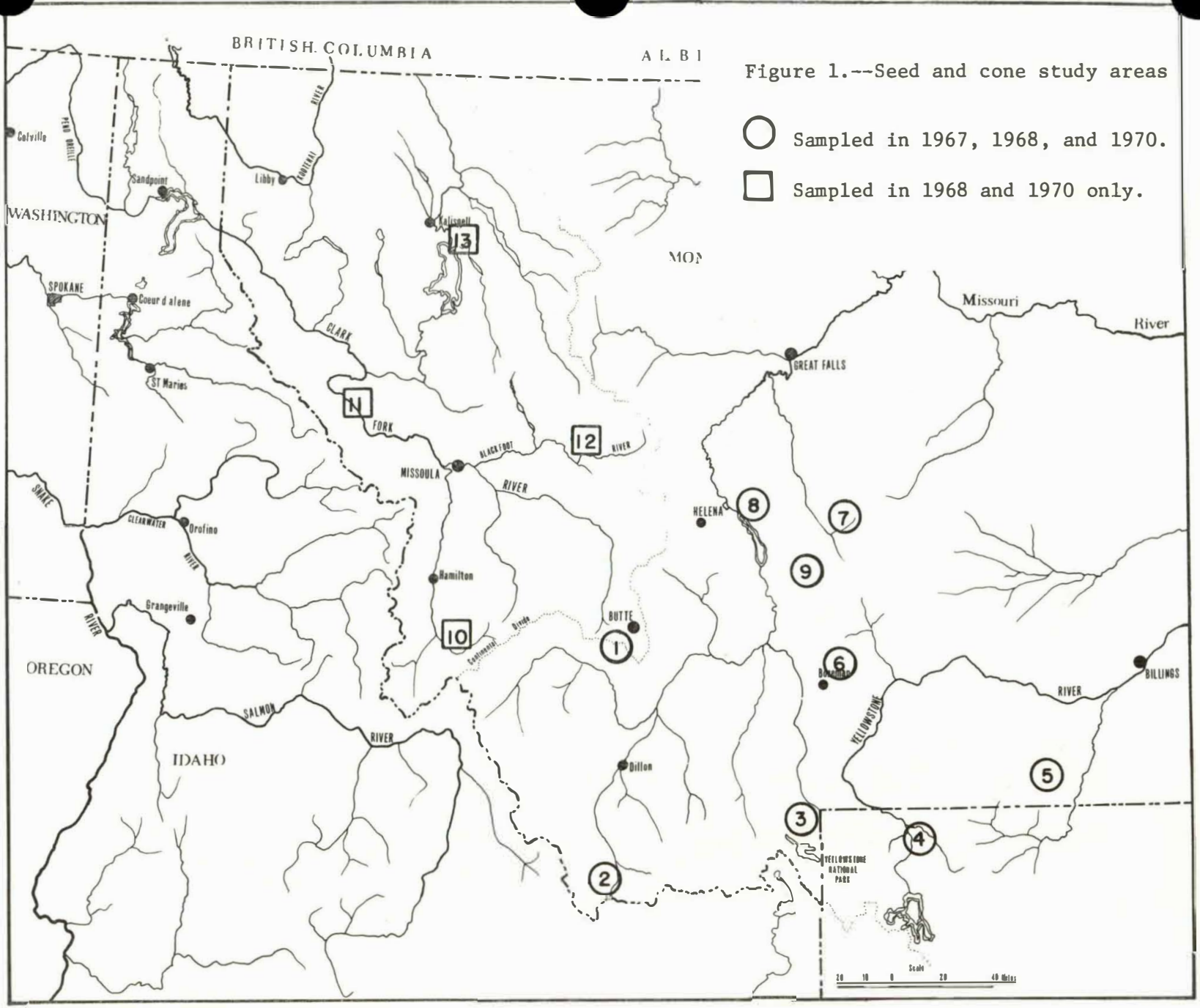


Figure 1.--Seed and cone study areas

○ Sampled in 1967, 1968, and 1970.

□ Sampled in 1968 and 1970 only.

Figure 2.--Dissecting cones in laboratory. Note rearing containers in background.

Seed extracted from cones collected in September was dissected to measure percent sound seed, hollow seed, and seed infested with the Douglas-fir seed chalcid, Megastigmus spermotrophus Wachtl. Two hundred sound or chalcid-infested seeds were dissected from each plot. Seed was extracted by shaking cones in paper bags. This method would tend to make the best seed most easily available, because seeds trapped in insect-damaged cones would not be extracted. This likely biased the results.

RESULTS

A moderate cone crop was produced in most areas in 1970. Insects caused visual deformity of nearly 55 percent of the cones collected. Much variability existed among the plots (Table 1).

Over 50 percent of the cones were classified as visibly deformed each year of the study (Table 2). Excessive resin exudation, distorted shape or external evidence of insect feeding were criteria used to determine deformation.

Table 1.--Percent of cones infested by plots, 1970.

Plot No.	Visibly deformed	Budworm	Midges	Cone worms (Dioryctria sp.)	Cone moth (Barbara colfaxiana)	Seed Chalcids*	Other insects
				PERCENT			
1	40.4	13.8	7.6	7.1	2.2	2.9	8.0
2	59.6	10.7	36.4	14.2	0	12.0	1.8
3	6.7	2.2	33.8	1.8	0	18.1	.4
4	30.4	7.6	8.9	5.8	8.4	5.0	2.8
5	28.9	4.9	39.1	4.4	3.1	1.0	3.1
6	25.8	16.9	10.2	1.3	0	1.5	.4
7	33.3	24.9	0	1.3	.9	0	0
8	96.0	48.0	4.9	24.9	79.1	-	3.1
9	59.1	50.7	3.6	8.4	.9	.5	2.8
10	72.9	64.9	.9	16.4	7.6	.5	.4
11	96.9	76.0	12.0	8.0	73.8	-	19.5
12	70.2	26.2	72.5	36.0	22.2	85.0	5.0
13	90.7	78.7	88.4	40.8	65.8	-	22.2
Average	54.7	32.8	24.5	13.1	20.3	9.7	5.0

* Percent of dissected sound seed infested.

Table 2.--Percent of Douglas-fir cones infested by seed and cone insects in western Montana and Yellowstone National Park - 1967-1970.

Year	Deformed cones		Western spruce budworm		Midges		Cone worms (Dioryctria sp.)		Cone moths (Barbara colfaxiana)		Misc. insects*	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
1967	54	19-91	36	9-71	39	14-84	- - - Combined in 1967 - Mean 4, Range 4-24			- - -	3	0-8
1968	62	28-98	-	-	17	0-71	12	.4-41	6	0-21	6	0-36
1970	55	7-96	33	2-79	25	0-88	13	1-41	20	0-79	5	0-22

* Does not include seed chalcids.

Four groups of insects were responsible for nearly all cone damage each year. The groups are western spruce budworm, Choristoneura occidentalis Freeman; midges, Contarinia washingtonensis Johnson, and C. oregonensis; cone worms, Dioryctria abietivorella (Grote) and D. pseudotsugella Munroe; and the cone moth, Barbara colfaxiana. The numbers of these species varied considerably from year to year and from plot to plot. There were 16 species of insects found feeding on the cones and 40 species of predators and parasites reared from the cones. The role of three species of insects reared from the cones is unknown (Table 3).

WESTERN SPRUCE BUDWORM.--Though budworm had not been reported as an important Doulgas-fir cone and seed feeding insect prior to this study (Dewey 1970), it was found to be the most damaging insect each year that this study was made. Budworms were found in the cones at all plots each year. As expected, damage to cones was more severe in budworm epidemic areas than in endemic areas. In 1967, three plots (6, 8, and 9) had aerially visible budworm defoliation. These plots averaged 55.7 percent of the cones budworm damaged, while the other six plots averaged 25.5 percent budworm damaged. In 1968, four plots (8, 9, 11, and 12) showed budworm defoliation aerially. Though the number of cones damaged by budworm was not determined, 92.5 percent of the cones on these plots were visibly deformed compared to 49.0 percent for the remaining plots. Three plots (9, 11, and 13) showed aerially visible defoliation in 1970. These plots averaged 68.3 percent budworm damaged compared to 22.0 percent for the other plots. The aerially visible defoliation never exceeded moderate. In areas other than study plots, where budworm defoliation was rated as heavy, it appeared that nearly 100 percent of the cones were damaged.

Budworm larvae feed on cones from second to final instars (sixth). Small larvae feed on the developing conelets, causing them to shrivel and die. Feeding on the more mature cones destroys cone tissue and seeds, often distorting cone shape severely and preventing normal seed dispersal. The possibility of reduced seed visibility from cones undergoing the stress of budworm feeding also exists.

DOUGLAS-FIR CONES AND SCALE MIDGES.--Midges were collected from each plot each year with the exception of plots 2 and 3 in 1968, and plot 7 in 1970. Due to a scarcity of cones, collections were not made at plots 2 and 3 after late July in 1968. This probably explains why no midges were found at those locations, for midges are most conspicuous in late August and September. Plots 5 and 13 averaged 59 and 57 percent respectively of the cones infested by midges for the course of the study. On the other extreme, plots 10 and 9 averaged 3 and 7 percent of their cones midge infested. In 1967 and 1968, only scale midges, C. washingtonensis were collected; but in 1970, the Douglas-fir cone midge C. oregonensis was also found.

Table 3.--Insects reared from Douglas-fir cones in Montana - 1967-1970.

Cone feeders

LEPIDOPTERA

Tortricidae:
Choristoneura occidentalis Freeman
Gelechiidae:
Chionodes sp.
Filatima sp.
Coleotechnites sp.
Olethreuthidae:
Barbara colfaxiana (Kearfott)
Griselda radicana (Walsingham)
Pyralidae:
Dioryctria abietivorella (Grote)
Dioryctria pseudotsugella Munroe

DIPTERA

Cecidomyiidae:
Contarinia washingtonensis Johnson
Contarinia oregonensis Foote
Lonchaeidae:
Earomyia barbara McAlpine
Lonchaea sp.

HYMENOPTERA

Torymidae:
Megastigmus spermotrophus Wachtl

HOMOPTERA

Aphidae:
Adeleges cooleyi (Gillette)

THYSANOPTERA

Thripidae:
Oxythrips sp.
Frankliniella sp.

Parasites and predators

HYMENOPTERA

Pteromalidae:
- *Zacalochlora milleri* Crawford
- *Mesopolobus* sp.

Eulophidae:
- *Tetrastichus strobilus* Burks
- *Tetrastichus barbarae* Burks
- *Tetrastichus* sp.
- *Elachertus proteoteratis* (Howard)
- *Elachertus pini* Gahan
- *Elasmus atratus* Howard
- *Elasmus* sp.
- *Hyssopus evetriae* (Girault)

Braconidae:
- *Apanteles fumiferana* Viereck
- *Apanteles aristoteliae* Viereck
- *Apanteles petrovae* Walley
- *Apanteles starki* Mason
- *Apanteles* sp.
- *Bracon cushmani* (Muesebeck)
- *Bracon* sp. apparently undescribed

Ichneumonidae:
- *Campoplex conocola* (Rohwer)
- *Campoplex* sp.
- *Scambus* (Scambus) *decorus* Walley
- *Scambus* (Scambus) *buolianae* (Ratzeburg)
- *Scambus* sp. probably new species
- *Phaeogenes hariolus* (Cresson)
- *Phaeogenes* sp.
- *Exeristes comstockii* (Cresson)
- *Glypta fumiferana* (Viereck)
- *Pterocormus dioryctriae* (Heinrich)
- *Temelucha rhyacioniae* (Cushman)
- *Exochus turgidus* Holmgren
- *Lissonota* sp.
- *Ichneuman* sp.

Torymidae:
- *Torymus* sp.

HYMENOPTERA

Eurytomidae:
Eurytoma sp.
Platygasteridae:
Leptacis sp.

DIPTERA

Tachinidae:
Actia sp.
Blondeliini sp.

COLEOPTERA

Cleridae:
Phyllobaenus sp. possibly *subfasciata* (LeConte)
Enoclerus sp. possibly *schaefferi* Barr.

HEMIPTERA

Miridae:
Deraeocoris rufusculus Knight

NEUROPTERA

Coniopterygidae:
Coniopteryx sp.

Miscellaneous cone associated insects

DIPTERA

Cecidomyiidae:
Asynapta keeni (Foote)

COLEOPTERA

Lathridiidae:
Lathridius minutus (Linnaeus)
Corticaria sp.

Scale midges feed mainly in the cone scale tissue, rarely feeding directly on the seed. Over 100 larvae have been found in a single cone. Hedlin and Johnson (1963), state that "larval feeding seems to cause the tissue around the seed to break down, resulting in soft, flabby seed."

The Douglas-fir cone midge was collected at four plots (1, 5, 12, and 13) in 1970. This insect causes a gall in the vicinity of the seed (Fig. 3). If the seed isn't destroyed, it usually is fused to the cone scale preventing it from being shed naturally or extracted if the cone was collected for seed. Heavily infested cones may have several midges in close proximity to the seeds, destroying all seeds in the cone.

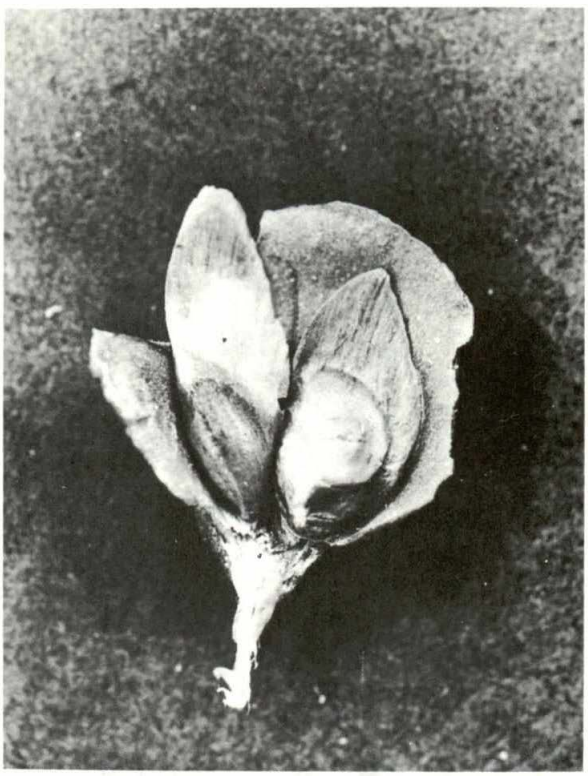


Figure 3.--Normal seed (left) and one galled by C. oregonensis.

CONEWORMS.--In the 1967 report, Dioryctria were lumped in a category called "other lepidoptera" which included all moths except western spruce budworm. This was done because this group infested a small percent (average 4 percent) of the cones and because we were unable to distinguish between some of the larvae that first year. In 1968 Dioryctria were counted separately but summarized as a group with all other lepidopterous insects. Cone worms were found at each plot, infesting an average of 9.8 percent of the cones (range 1.3 to 38.7 percent). Again in 1970, Dioryctria were collected at each plot. They infested an average of 13.1 percent of the cones (range 1.3 to 40.8 percent).

Both species, D. abietella and D. pseudotsugella (Fig. 4), were collected from each plot; however, D. abietella was more abundant.

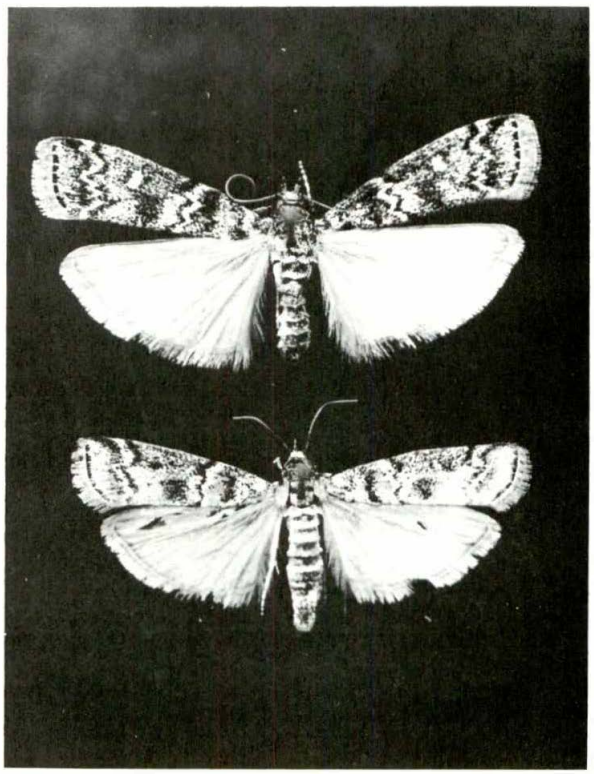


Figure 4.--Adult D. abietella (top) and D. pseudotsugella

CONE MOTHS.--Barbara colfaxiana were more numerous and widespread in 1970 than the other years of the study. They were found at all but one plot in 1970 and infesting averaged 20.3 percent of the cones. Plot eight had 79.1 percent of its cones infested with cone moths. In 1968, eight plots had cone moths, and 5.7 percent (range 0 to 21 percent) of the cones were infested. Less than 4 percent of the 1967 cones were known to contain B. colfaxiana.

SEED CHALCIDS.--Megastigmus spermotrophus infest only the seeds. One larva completes its development in one seed (Fig. 5). As a result a large population must exist to be significantly injurious to the seed crop.

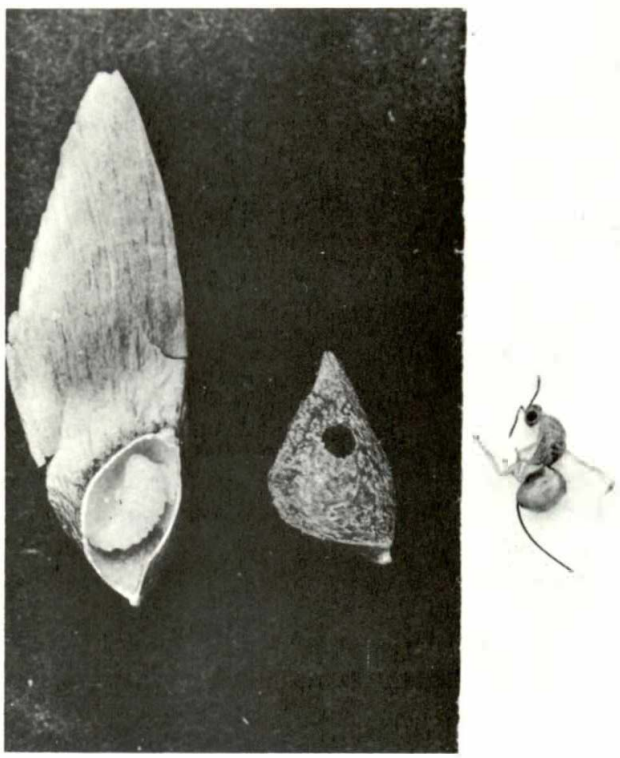


Figure 5.--Seed with chalcid larva; seed showing emergence hole; and female adult chalcid.

In 1967, 2,700 seeds (300 per plot) were dissected for chalcid evaluation. Over 45 percent of these were unexplainably hollow. Only about 1 percent of the seed was infested with chalcids. Seeds were not dissected in 1968. Dissections were made on 4,703 seeds in 1970 (Table 4). Seed dissections were not made on plots 8, 11, and 13 because an insufficient number of seeds could be found due to the excessive insect damage. At all other plots, seeds were dissected until 200 seeds that were sound or contained chalcids had been counted. Chalcids infested an average of 5.4 percent of the seed (range 0 to 11.6 percent). An average of 55.9 percent (range 12.3 to 79.4 percent) of the seed was hollow.

Table 4.--Seed dissection data - 1970

Plot No.	Total seeds dissected	Percent hollow	Percent with chalcids	Percent sound
1	342	36.1	1.7	39.8
2	522	61.7	4.6	33.7
3	407	36.1	11.6	52.3
4	228	12.3	4.4	83.3
5	496	59.3	.4	40.3
6	337	39.9	.8	59.3
7	338	40.8	-	59.2
9	461	56.4	.2	43.4
10	599	66.4	.2	33.4
12	973	79.4	16.6	4.0
Total	4,703	55.9	5.4	38.7

OTHER INSECTS.--Aphids, thrips, seed maggots, and/or several additional Lepidoptera larvae were found at most plots of most collections. Although aphids were quite numerous, it is difficult to accurately assess the damage caused by a juice-sucking insect. Aphid damage would probably be in the form of less vigorous cones, or less viable seed. Griselda radicana (Fig. 6) was the most commonly occurring of the miscellaneous Lepidoptera. Prior to this study it had not been reported from Douglas-fir cones.

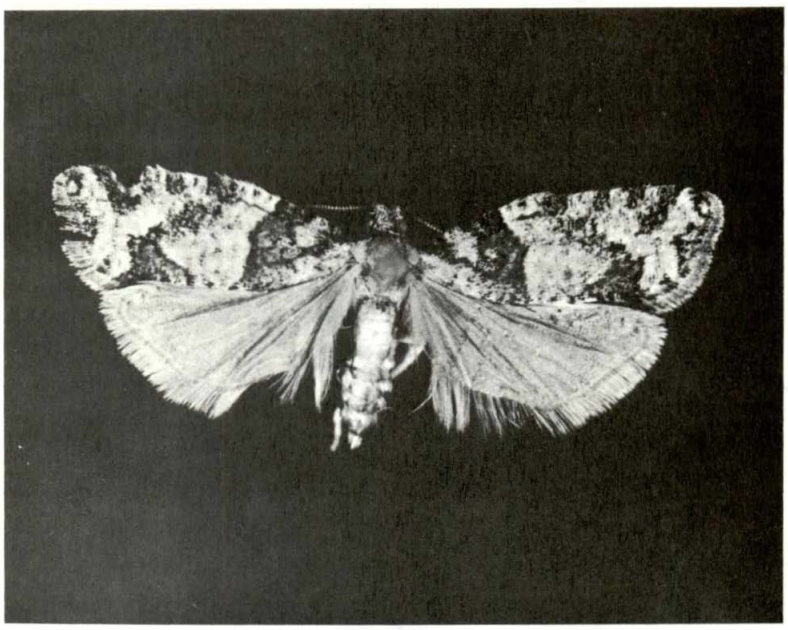


Figure 6.--*Griselda radicana* adult.

DISCUSSION

In order to thoroughly understand the role cone and seed insects have on regeneration, records would need to be reviewed of regeneration success during years of various insect population levels. Such records are nonexistent, making statements of absolute numbers of new trees affected impossible. Yet, from the data collected, generalizations can be drawn to the effect that cone and seed insects have the potential and in several locations do seriously retard natural regeneration of Douglas-fir in Montana. For example, in 1970 plot number 13 had 78 percent of its cones infested with budworm, 66 percent infested with cone moths; 41 percent infested with cone worms; 22 percent infested with other lepidopterous larvae; and 88 percent of the cones infested with midges. Attempts to collect seeds to dissect for chalcid evaluation were futile for virtually 100 percent of the seed had been destroyed. Similar situations existed at plots 8, 9, 11 and 12 and to a lesser degree in most other plots.

Douglas-fir cone crops are very irregular in occurrence. Eliminating other factors, the cone crops will go from heavy to almost complete crop failure. This seems to follow a cycle of about 4 to 7 years. In 1967, a heavy cone crop was produced; it was light in 1968; and moderate in 1970. As expected, ordinarily the smaller the cone crop the higher the percent of infested cones. However, in 1967 midges infested 84 percent of the cones at one plot and budworm infested over 71 percent of the cones at another plot. On the other hand, in 1968 as many as 72 percent of the cones at one location showed no insect damage. This indicates that more is involved than cone crop size in determining percent of cones infested.

Insects that are dependent upon cones are probably more acutely affected by fluctuations in cone crops than are insects that are not dependent on the cones. During years of near cone crop failure, cone-dependent insects are likely to have such severe competition that many fail to complete their development. This would reduce their numbers the following year. Insects like budworm and Dioryctria pseudotsugella successfully develop on the foliage. These insects would be less affected by fluctuations in cone crops.

Budworm are recognized primarily as foliage feeders. During epidemic conditions they cause serious defoliation. In areas of endemic populations, budworm often appear to prefer the cones, infesting a high percent of them and feeding very little on the foliage. Preliminary data indicate that budworm feeding on cones complete their development about one instar sooner than those feeding on foliage. Whether this is because the cones are more nutritious or merely because they begin feeding on them sooner is unknown. It is also unknown what, if any, effect a straight cone diet has on fecundity, longevity, etc. A budworm feeding inside a hollowed out cone is probably more difficult to contact with an aerial spray than one feeding on the foliage.

It is difficult to evaluate the damage caused by insects that do not destroy the seeds outright. Midges, aphids, cone maggots, some cone worms, etc., may feed only on juices or scale and bract tissue and never feed on the seed; yet they may affect it tremendously. Johnson (1963), found cone scales heavily infested with Contarinia washingtonensis produced less viable seed. He found seeds from these cones averaged less than 2 percent filled compared to nearly 60 percent filled from uninfested cone scales. Forty-three percent of the seeds from the uninfested cone scales germinated while only 2 percent of the heavily infested seed did so.

The Douglas-fir cone midge causes a gall in the vicinity of the seed, preventing it from being shed during normal seed dispersal. Only after extensive germination tests will the importance of nonseed destroying insect feeding be determined.

After the seed is shed it is still subject to depredation by insects, birds, and rodents. Gashwiler (1967) found during a 2-year study in Oregon that 88 percent of the Douglas-fir seed that reached the ground was destroyed by birds, small mammals, and other agents before germination.

With so many agents hindering normal seed development and germination, it is understandable why unsatisfactory natural regeneration is not uncommon. This problem will undoubtedly continue to some degree as long as timber is harvested.

CONTROL

After an area has been harvested, the land manager is anxious to get it back into production. It is often unacceptable to wait for up to 7 years for a good cone crop that may be destroyed by insects. As a result, more and more emphasis is being placed on artifical restocking. This places a greater demand on high quality seed for nursery stock. The tendency is toward the use of seed orchards or seed production areas. With the extra expenditures in these areas, the losses due to insects cannot be tolerated. Though large-scale control methods are not available for cone and seed insects, some promising materials and techniques for seed orchards are being developed. Timing is critical to assure getting the insecticide to the insect when it is most susceptible. When more than one insect species is of concern, dual applications and perhaps dual insecticides may be required. Some of the systemic insecticides are showing promise. These materials are translocated to the cones and destroy insects when they feed on the cones.

Silvicultural and integrated control methods must also be developed and perfected in order to keep losses caused by these insects at tolerable levels.

ACKNOWLEDGEMENTS

The author would like to acknowledge the expertise of Clinton E. Carlson, Pathologist, for the photography in this report. Appreciation is also extended to Hubert E. Meyer, Biological Technician; Carma Gilligan, Biological Lab Technician; and Beryl Wilson, Judy Johnson, Alice Green, and Tom Quarles, seasonal assistants, for their efforts in cone collection and dissections. Insects were identified by Norman E. Johnson, Weyerhauser Company, New Bern, North Carolina; D. A. Ross, Forest Research Laboratory, Victoria, B. C., Canada; A. Mutuura, Ent. Research Institute, Ottawa, Ontario, Canada; J. F. McAlpine, Entomology Division, Ottawa, Ontario, Canada; R. M. Marsh, B. D. Burks, R. W. Hodges, L. M. Warner, D. R. Davis, C. W. Sabrosky, and R. J. Gagne of the U.S. National Museum, Beltsville, Maryland.

LITERATURE CITED

Dewey, J. E. 1969. Results of a Douglas-fir cone and seed insect study in Montana and Yellowstone National Park 1968. Unpub. report. 9 pp., U.S. Forest Service.

Dewey, J. E. 1970. Damage to Douglas-fir cones by Choristoneura occidentalis. Jour. of Econ. Ent. Vol. 63, No. 6.

Dewey, J. E., and F. W. Honing. 1968. A study of insects attacking Douglas-fir cones in eastern Montana and Yellowstone National Park 1967. Unpub. report. 15 pp., U.S. Forest Service.

Gashwiler, J. S. 1967. Conifer seed survival in a western Oregon clearcut. Ecology 48(3):431-438.

Hedlin, A. F. 1960. On the life history of the Douglas-fir cone moth, Barbara colfaxiana (Kft.) (Lepidoptera:Olethreutidae), and one of its parasites, Glypta evetriae Cush. (Hymenoptera: Ichneumonidae). Canadian Entomologist Vol. XCII, No. 11.

Hedlin, A. F., and N. E. Johnson. 1963. Life history and habits of a midge, Contarinia washingtonensis Johnson (Diptera:Cecidomyiidae), in Douglas-fir cones. Canadian Entomologist Vol. 95, No. 11.

Johnson, N. E. 1963. Cone scale necrosis and seed damage associated with attacks by Douglas-fir cone midges. Forest Science Vol. 9, No. 1.

Johnson, N. E., and H. J. Heikkenen. 1958. Damage to the seed of Douglas-fir by the Douglas-fir cone midge. Forest Science, Vol. 4, No. 4.

Wilson, A. K., and J. S. Spencer, Jr. 1967. Timber resources and industries in the Rocky Mountain states. U.S. Forest Service, Res. Bul. INT-7.

3832